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The Macroeconomic Impact of ECB's Large Scale Asset Purchases: A Proxy SVAR Approach

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Abstract

I study the ECB's policy announcement effects in various assets in order to assess how many distinct information dimensions are systematically assimilated. Wielding the zero lower bound, I isolate non-standard measures from conventional monetary policy, ineffective since 2016. Transforming these into an external instrument for a SVAR Model, I conclude that expanding the overall central bank's balance sheet increases consumer prices while production may remain unaffected. I find that both the exchange rate and long term yields depress as a result. Notwithstanding, credit conditions do not benefit from this. Finally, both equity returns and expectations fall whereas market volatility rises.

JEL Codes: *E31, E44, E52, E58.*

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1 Introduction

The resort to non-standard monetary policy measures by several central banks around the world has generated controversy on their effectiveness among researchers and practitioners alike. The European Central Bank (ECB) in particular has been legally challenged over several asset purchase programmes. Despite having won most of these legal fights, the disapproval of these measures is driven by the uncertainty surrounding their effects. Theory has provided several examples on how these measures can successfully increase prices, but does, nevertheless, also leave room for possible ineffectiveness. Furthermore, the set of potential transmission channels is vast and each one of these may have different economic consequences (see Joyce et al. (2012) for an introduction). As such, it is of vital importance to understand if these measures can be confidently added to a central banks' tool-set. More specifically, it is mandatory that we understand the full economic consequences of the already implemented policies in the eurozone.

The literature has divided non-standard measures into three categories (Bernanke et al., 2004), namely: communication policies steering expectations, the composition and the size of the central bank's balance sheet. For our macroeconomic analysis we focus on the latter, the one less explored but with the most potential for contribution without access to proprietary data.

Consequently, using a SVAR model identified through external information, I provide evidence that increasing the ECB's balance sheet increases consumer prices in the euro area, nonetheless, output may remain completely unchanged. In fact, credit does not appear to benefit from these measures. Neither the volume nor the cost of credit suffer any change from an unexpected structural large scale asset purchase. Moreover, financial markets become more volatile while both financial sector and overall eurozone stocks' market returns decrease. On top of this, business expectations deteriorate while inflation expectations do not significantly rise. Lastly, we can notice that both the long term risk free interest rate and exchange rates decrease as a result of these policies.

Most of the ECB's information on monetary measures is conveyed during their regular policy announcements. As soon as these actions are revealed, the information should have an impact on agents' behaviour. As a result, they provide an extensive field of opportunities to assess the consequences of the different measures imposed. Following the literature on central

banking communication (see Blinder et al. (2008)), we build on past work and construct a way of extracting information from these events. As such, by making use of the bank's effective zero lower bound, we provide a structural interpretation to the statistical decomposition conducted, successfully extracting information on at least part of the non-standard actions intended to affect longer term interest rates, as interpreted by financial markets.

As a follow up, I construct an instrumental variable which proves useful for use in an external identification strategy for a simple SVAR model. Despite the strict assumptions, this methodology avoids the use of narrative strategies¹.

In sum, this work contributes twofold to the existing literature. Firstly, I assess the number of systematic dimensions needed to describe asset movements during ECB's post-crisis policy announcements, while constructing a new strategy to structurally interpret them. Secondly, I show that this methodology's results are useful also for assessing the macroeconomic effects of non-standard monetary measures, providing evidence contradicting previous works' conclusions of improved expectations, credit conditions as well as higher equity prices, as a result of a balance sheet expansion.

The rest of the paper proceeds as follows. Section 2 presents a brief literature review on relevant past work. Section 3 details the econometric framework, followed by the construction of an external instrument in section 4. Section 5 presents the data and estimation results on the macroeconomic analysis while section 6 provides some concluding remarks.

2 Literature Review

This section begins by presenting an overview of the literature on financial assets' responses to unconventional monetary policy and finishes by delving into the empirical work assessing the real effects of central bank's asset purchases.

¹Questionable given the particular uncertainty surrounding the topic.

2.1 Market Responses to Unconventional Monetary Policy

This work's outcome encompasses two seemingly distinct strands of literature on monetary policy in the euro area. The first assesses how financial markets react to unconventional monetary policy and is, therefore, related to the financial economics literature. The second inspects the macroeconomic effects of increasing a central bank's balance sheet size.

Starting with the former, most work has relied upon event studies on days of policy announcements, inspecting the reactions of asset values around a relatively narrow time window on these particular dates. Its reasoning follows from the objective of determining the causal impact of non-standard measures, whose information is firstly conveyed during policy announcements, on financial markets. As such, by restricting the sample one is able to isolate financial asset movements from other confounding factors. Additionally, the potential problem of endogeneity is absent since no space is given for the central bank to react.

These approaches require a narrative selection of the relevant days for analysis. Motto et al. (2015) include both ECB's press conferences and the president's topic related speeches on their set of events. The broad group of dates implies the need to control for other macroeconomic news, as these may also have an impact on asset prices. Their use of event dummy regressions is, nevertheless, prone to criticism. Asset movements must uniquely reflect new and unexpected facts since all other pre-available information must have been priced in already. As such, what may be an expansionary policy can still result in a negative market reaction. As long as the policy falls short of their expectations, the changes in values will not reflect the true nature of the central bank's actions. In more practical terms, this may bias the results to the point of establishing the incorrect causal relationship between policies and asset movements, specially given their non-discriminatory use of all press conferences. Fratzscher et al. (2016) treat non-standards policies slightly differently. They too use event dummy regressions for policy announcements but select just a handful of events, with a significant and proven enough magnitude, that faced little to no anticipation by the markets. In contrast, they create a surprise indicator for two other specific policies, liquidity injections and the securities market programme. For the former, they resort to an indicator that assesses loan expansions in a 7 day window around their respective auctions. For the latter, they construct a bank's reaction function to identify exogenous changes

in bond purchases for a given week. Both works find evidence for a decrease in sovereign yields, credit spreads and a rise in both inflation expectations and equity markets as a result of the policies. Contrarily, they do not find consensual results regarding the the exchange rate.

Varghese and Zhang (2018) in turn, attempt to avoid the dummy regression's pitfall by constructing a measure that captures only the unexpected changes in policy. They do so by estimating two factors that describe a portfolio of sovereign yields' individual reactions on days of announcements and rotate them using the varimax method. Despite having no structural interpretation whatsoever, they find that one factor loads more on short term yields while the other loads more on longer term ones. In addition, they observe that the latter is more active after the implementation of quantitative easing. They, therefore, naturally interpret them as being depicting of conventional and unconventional monetary policy, respectively. Ultimately, their work yields similar results to the two previous papers and records a meaningful reaction for the exchange rate.

2.2 Non-standard Measures and the Macroeconomy

Only until recently have empirical macroeconomists had a sufficiently high sample to study the systematic implementation of asset purchases in the euro area.

As such, a big deal of work focuses on specific non-standard programmes. Gambetti and Musso (2017) assess the impact of the 2015 extended asset purchase programme while Wieladek and Pascual (2016), following the methodology of Weale and Wieladek (2016), study how quantitative easing has impacted the eurozone's aggregate macroeconomy from 2012 to 2016. Both studies rely on Bayesian VARs with non-informative priors while the former also uses a time-varying parameter model with stochastic volatility. This latter methodology proves useful in taking into account the structural changes occurring in the economy, as well as the more tumultuous periods during the sample. To circumvent the lack of data Gambacorta et al. (2014) take an alternative route, estimating a panel VAR that captures the cross sectional variation in the economic impact of an expansion in a central bank's balance sheet.

Wieladek and Pascual (2016) use as the indicator variable a non-decreasing series of the total amount of euro area sovereign debt purchases, announced at each ECB's policy meeting,

scaled by the euro area's GDP. Alternatively, the other two works choose the amount of total assets in the central bank's balance sheet.

All their methodologies rely on a mixture of zero and sign restrictions in order to identify their models and assess the effect of an expansionary purchasing policy. These strategies first drawback is failing to take into account expectations on monetary actions. As one will see further along this work, several negative financial markets' reactions may occur even when policy announcements are deemed expansionary.

Wieladek and Pascual (2016) use two identification strategies. Both assume equity prices and asset purchases increase while one of them adds that long term interest rates should decrease, both on impact and for the following 5 months. Gambetti and Musso (2017) assume an increase of the balance sheet size and a decrease on impact of sovereign yields, persisting for three more quarters. Moreover, they assume a positive impact on both output and prices with one, two and/or three lags. Finally, Gambacorta et al. (2014) set an expansion of the balance sheet, a zero response on impact for both prices and output and exclude a possible rise in market volatility. Most of these restrictions, even if heavily based on economic theory, do not allow for a first agnostic assessment of non-standard measures' real impact, further motivating my work.

Their results show an increase in both output and prices but with various degrees of persistence. On average, though, output growth tends to be shortly lived, while the increase in prices tends to persist for longer. Contrarily, the persistence of the long term interest rate's depression has a higher variability among studies.

Finally, those inspecting transmissions mechanisms conclude for the existence of a portfolio rebalancing, exchange rate, inflation expectations and signalling channels. Surprisingly, those who leave it unconstrained also find an increase in uncertainty after the implementation of unconventional monetary policy, as portrayed by financial markets' volatility.

3 Econometric Framework

In this short section, following Stock and Watson (2016), I start by presenting the simple structural vector auto-regression, ultimately used for assessing the effects of large scale asset purchases, and finish by explaining how identification proceeds using an external instrument.

3.1 The Structural Vector Auto-regression Model

In order to study the effects of monetary policy, one must be capable of capturing the structural co-movement of economic variables to, therefore, identify exogenous changes to the economic system. The vector auto-regression (VAR) framework does just that, thus, allowing the researcher to observe how an economic environment naturally reacts to an unforeseeable shock.

That being said, consider X_t to be a column vector of n economic variables at time t . The VAR model is depicted by the following equation:

$$X_t = \mu + \Gamma_1 X_{t-1} + \dots + \Gamma_p X_{t-p} + \zeta_t, \quad (1)$$

where ζ_t is a column vector of n innovations, p is the number of lags in the model, Γ_p an $n \times n$ matrix of parameters and μ a column vector of n intercepts. Equation (1) is called the reduced-form VAR. It can be equivalently represented as

$$\Phi(L)X_t - \mu = \zeta_t, \quad (2)$$

where $\Phi(L)$ is an $n \times n$ matrix of lag polynomials of order p . The model, thus, describes a random-variable's mean process as being a function of other variables' realizations and lagged values of the system. Additionally, all variables are assumed second order stationary and integrated of order zero. Without making any distributional assumptions about the reduced-form errors, the model may be suitably estimated using ordinary least squares.

Since we are interested in the structural shocks $\varepsilon_{i,t}$ we need to represent X_t not in terms of its reduced-form errors but as a function of the underlying uncorrelated structural innovations,

$$\Sigma_\varepsilon = \text{diag}(\sigma_{\varepsilon_1}^2, \dots, \sigma_{\varepsilon_k}^2). \quad (3)$$

From the general structural VAR model, there is a linear relationship between the reduced-form errors and the structural shocks,

$$\zeta_t = H\varepsilon_t, \quad (4)$$

where H is an $n \times n$ matrix and ε_t is a column vector of n structural shocks. Using the addi-

tional assumption of invertibility, standard in the literature, the structural shocks can then be represented as a linear transformation of the reduced-form errors,

$$H^{-1}\zeta_t = \varepsilon_t, \quad (5)$$

and we may assess how the system reacts to any unexpected change.

3.2 External Identification

SVAR models suffer from a well known problem of identification, i.e., of retrieving matrix H from the reduced-form estimates. The most sought after solution is to impose internal restrictions to the model, most notably, sign or timing restrictions. Even at a monthly frequency the endogenous behaviour of an economic system, to which the central bank belongs to, does not allow one to plausibly define which economic variables inertially react to others, invalidating the latter approach. Sign and zero restrictions, in turn, require complete certainty about the quantitative evolution of some specific variables in reaction to a large scale asset purchase. The literature cannot have such conviction yet since, as argued before, not only does theory not grant us assurance of its effectiveness but there can also be a multitude of mechanisms at play.

With an alternative approach in mind, Montiel Olea et al. (2012) propose to use information not embedded in the model. In practice, this strategy works by using some variable as a proxy for the structural shock of interest. Consequently, in order to estimate (part of) matrix H , we only require a single instrumental variable, Z_t , also referred to as an external instrument². To be suitable, the instrument must respect two assumptions, common to those familiar with the microeconomic literature:

1. Relevance: $E(Z_t \varepsilon_{1t}) = \alpha \neq 0$
2. Exogeneity: $E(Z_t \varepsilon_{jt}) = 0, j = 2, \dots, k$.

These amount to having an instrument correlated with the structural shock of interest, ε_1 , but uncorrelated with the other structural shocks.

²The term external derives from its exterior origin to the model.

Given that we are solely interested in identifying a single unanticipated structural disturbance, the balance sheet expansion, we just require part of H to be known, namely its first column³. Partition H into its first column, H_1 , and the remaining, H_{-1} , and write

$$E(\zeta_t Z_t') = E(H \varepsilon_t Z_t') = \begin{bmatrix} H_1 & H_{-1} \end{bmatrix} \begin{bmatrix} E(\varepsilon_{1t} Z_t') \\ E(\varepsilon_{-1t} Z_t') \end{bmatrix} = H_1 \alpha', \quad (6)$$

where we have used equation (4) for the first equality and the two assumptions of the instrumental variable for the last. We may now note that the regression of the instrument on the reduced-form innovations identifies the structural shock of interest up to a constant. Note that we may normalize H 's first entry to one. This is denoted as a unit normalization and fixes the sign and scale of the first shock such that a unit increase in ε_{1t} increases ζ_{1t} by one unit. We can now rewrite the last equality as

$$H_1 \alpha' = \begin{bmatrix} \alpha' & H'_{-1,1} \alpha' \end{bmatrix}', \quad (7)$$

where $H_{-1,1}$ is the column vector which excludes the first entry of H_1 . Consequently, we obtain H_1 ,

$$H_{-1,1} = \frac{E(\zeta_{1t} Z_t')}{E(\zeta_{-1t} Z_t')}. \quad (8)$$

On top of its interpretational advantages, Stock and Watson (2016) point out that this unit normalization further decreases potential inferential error when computing the structural impulse response functions. Without loss of generality, we may disregard the mean μ and define these using equations (2) and (4):

$$X_t = \Phi(L)^{-1} H_1 \varepsilon_t + e_t. \quad (9)$$

As can be concluded, the success of this approach relies heavily on the ability to find relevant and credibly exogenous instrument(s). The literature already has some examples covering mostly conventional policy, but has still failed to properly construct one which isolates non-standard measures. I attempt to do so in the next section.

³We need to order first the variable whose shock we are interest in.

4 External Instrument

In this section I start by providing a brief overview of the ECB's post-crisis policy history, following Micossi (2015), succeeded by an analysis of the ECB's press releases. I then construct the external instrument and finish by validating the series generated through the inspection of some financial assets' responses.

4.1 Extracting Information from ECB's Announcements

The European Central Bank has been regularly resorting to non-standard measures of monetary policy ever since the beginning of the financial crisis. Around that time, the central bank introduced credit enhancement policies, such as increased maturities for refinancing operations with full allotment, and the first covered bond purchase programme, aimed at maintaining liquidity in the interbank and financial markets. Sequentially, during the turbulent times of the sovereign debt crisis in the euro area, the ECB launched a series of asset purchase⁴ programmes to restore markets' depth and liquidity. Notwithstanding, the subsequent banking crisis required a mix of conventional and non-standard monetary measures as portrayed by, for example, the decrease of official refinancing interest rates or by furthering their respective term of operations, respectively. After these unsettling periods, poor macroeconomic outlooks and deflationary pressures set the stage for further use of non-standard measures, now with the intent of stimulating the economy and raising inflation. Consequently, the central bank started to further quantitative easing policies, more meaningfully after 2015, continued to decrease official rates and gave a much more important role to steering expectations, providing forward guidance to the markets on their future policies. As a result of this tumultuous period, the central bank's balance sheet rose from around 190 thousand million euros in total assets in early 2007 to around 2704 thousand million euros in the third quarter of 2018. With this in mind, it is easy to conclude that both conventional and unconventional mechanisms, in particular balance sheet size measures, were systematically at play during the period described.

That being said, the literature on monetary policy communication is particularly interested in understanding how central banks' information is conveyed to the public. The core of this re-

⁴In secondary markets.

relationship is composed of two parts. The first is related to central bank's communication intentions, i.e., what type of message it is trying to convey to the public. Oppositely, its counterpart is related to how agents actually interpret this information. Surprisingly enough, Gürkaynak et al. (2005) - GSS hereafter - show that, in the US, the somewhat complex responses of a variety of financial assets in days of policy announcements can be well described using a very reduced number of common drivers. To achieve such conclusion, the authors test for the number of dimensions necessary to describe the individual movement of a group of financial assets around policy announcement days. Broadly speaking, this statistical decomposition characterizes the number of distinct information factors markets systematically internalize from these events. I here replicate that same approach to understand how markets react to the ECB's regular policy announcements.

Take Y to be a $T \times s$ matrix representing the bundle of s financial assets⁵. The factor model can be depicted by the following equation:

$$X = F\Lambda' + \psi, \quad (10)$$

where Λ is an $s \times k$ matrix of factor loadings, F is a matrix of $T \times k$ unobserved factors and ψ is a $T \times s$ matrix of idiosyncratic components. The unobserved factors can be estimated using non-parametric methods such as that of principal components, which do not assume any specific distribution for the disturbances. The use of cross-sectional averaging removes the influence of the idiosyncratic errors and leaves only the variation associated with the common factors⁶. Consequently, estimation proceeds in two steps. Firstly, one retrieves the k largest eigenvectors, in descending order, of the covariance matrix of Y , thus, obtaining the loadings matrix. Hence, normalization $\Lambda'\Lambda = I_k$, which is arbitrary and entails no economic interpretation, is used inconsequently. Secondly, one multiplies the loadings matrix by the data to obtain the unobserved components.

We set out to test how many unobserved factors are necessary to describe Y well up to an idiosyncratic disturbance. The statistical tool used is that of Cragg and Donald (1997)'s matrix

⁵Suitably normalized to have unit variance.

⁶This approach estimates the factors consistently up to a pre-multiplication by an arbitrary $k \times k$ rotation matrix.

rank test. It tests the null hypothesis that Y is well described by k_0 unobserved factors against the alternative of $k_A > k_0$ factors. In short, the algorithm starts by finding the minimum distance between the covariance matrix of the data and that of a model with k_0 factors. Remember that this entails searching over all possible factor loadings for the model. Under the null hypothesis this is a Wald statistic with limiting χ^2 distribution⁷.

The bundle is comprised of nine financial assets. An euro area broad equity index, STOXX50, an investment grade fixed-rate euro area bond option adjusted spread index, LECPOAS, the one, five and ten-year German bond yields index, the one-year inflation swaps index⁸ and the one, six and twelve-month euro overnight index average (eonia) swaps index. The series span from January 2008 to March 2018, amounting to 111 press releases, and extends the corresponding list of events from Corsetti et al. (2018), hence, capturing the period described before, when non-standard measures were used systematically. All data was retrieved from Bloomberg.

The ECB's policy information releases occur in two parts. At 13:45 CET, they convey a limited amount of information on their latest policy actions. Not only but most importantly, they indicate the marginal refinancing operation, deposit facility and marginal facility rates. Later, at 14:30 CET, there is a press conference and Q&A session with the President, which normally lasts an hour. Following the previously explained reasoning, the event window should roughly span this intra-day period. Problematic, nevertheless, is the process of retrieving intra-day data. As such, with the exception of the equity index, all the market reactions are computed as the difference between the closing and opening⁹ values on event days. In turn, for the stock index, we use the difference between the index value at 16:00 CET and 12:35 CET. Intra-day data on this index is available on Bloomberg only from 2008 onwards. Notwithstanding, GSS find evidence that this does not pose a significant limitation to the analysis at hand. Once more, with the exception of stocks, the other assets' responses tend to be slower and the results remain relatively similar when using either smaller or relatively wider event windows.

Following up, not only does the rank test vehemently reject the hypothesis that there are no systematic responses to policy announcements but it also presents statistical evidence, at a

⁷See Gurkaynak et al. (2005) for more details

⁸Represents the fixed leg yield of the trade.

⁹When not available, the previous trading day's closing 'price' is used.

10% significance level, of requiring only 3 factors to systematically describe the data up to an idiosyncratic disturbance:

Null Hypothesis:	$k_0 = 0$	$k_0 = 1$	$k_0 = 2$	$k_0 = 3$	$k_0 = 4$
Alternative Hypothesis:	$k_A > 0$	$k_A > 1$	$k_A > 2$	$k_A > 3$	$k_A > 4$
P-value:	0.000	0.012	0.055	0.169	0.425

These results, however, are not completely robust to the inclusion of more assets. On the one hand, we consistently find evidence for more than two latent factors. This leads us to conclude that more than conventional monetary policy is at action during this period. On the other, the number of factors oscillates between three and four¹⁰. These observations corroborate GSS's statement that adding strongly correlated assets produces additional factors, even though their variation may be orthogonal to that of others. Likewise, these assets were individually chosen so as to depict a comprehensive number of policy responses' characteristics. Analogous to Swanson (2017) for the US, the six and twelve months eonia swap provide a good estimate of market expectations on the future path of rates over the one year horizon. German bonds grant information on longer horizons' risk premia and interest rate expectations. Additionally, the one year inflation swap conveys market expectations on the inflation rate in that horizon. Simultaneously, the equity and spread indices both convey expectations on economic performance, whereas the latter also depicts credit risk premia. The economic information provided during announcements is studied by Jarocinski and Karadi (2018) as an information channel and is shown to have a meaningful impact on business conditions' prospects. Lastly, the one month eonia swap is used as a proxy for predictions on short term rates, being crucial for our analysis.

These interpretations are supported by Kuttner (2001) who shows that such future type assets are able to gauge market's expectations and, therefore, isolate the unexpected component of policy, which is what we are ultimately interested in.

¹⁰When one adds, for example, Italian bonds, which all have a higher than 30% correlation with high maturity german bonds during the sample, or other maturities for the already included assets.

4.2 Constructing a Proxy Series for Non-standard Policy

The factors estimated before, nonetheless, do not have any straightforward meaning, as they are simply data-driven structures. One way of circumventing such problem, introduced by GSS, is to rotate these latent structures such that they offer the desired structural interpretation. Take F to be the 111×3 matrix of latent factors estimated using principal components. We can rotate the factors using a 3×3 orthogonal matrix U , generating a new matrix of unobserved factors, Z :

$$Z = FU. \quad (11)$$

Notice that this rotation preserves the variation explained by the factors¹¹. Concurrently, the rotated factors remain orthogonal to each other.

It is straightforward to show that we need to set three restrictions on the (orthogonal) rotation matrix in order to have it uniquely defined. With such purpose, I follow a very similar approach to that of Swanson (2017). The first two restrictions are crucial in reaching our goal of constructing an instrument(s) that only portray unexpected changes to non-standard measures. With that objective in mind, remember that the one month eonia swap depicts agents' expectations on the next month's short term interest rate. Following GSS, we thus isolate two factors¹², Z_2 and Z_3 , from explaining any change in this rate. Essentially, we want them to represent all other aspects of announcements that do not move the current short rate. Consequently, they should only reflect alternative actions or, more broadly speaking, non-standard monetary actions built to affect longer term maturities, such as forward guidance or most of the asset purchase programmes. The remaining factor, Z_1 , is referred to in this literature as the target factor and should be the only one affecting the short rate. The choice of the first factor, F_1 , which explains the most variability, to depict conventional measures is based on the fact that these, on top of being present in almost the whole sample, were already familiar to the public whom, consequently, should have more predictable and systematic reactions to them.

Contrarily to Swanson (2017), whose rotated factors each uniquely represent either forward

¹¹The 9×3 matrix of factor loadings is also rotated: $\Lambda^* = \Lambda U$. This means that the common components of the data will now be: $X = Z\Lambda^{*'} = (FU)(\Lambda U)' = FUU'\Lambda' = F\Lambda'$, exactly as before the rotation. We used here the fact that U is orthogonal.

¹²Referred to as UMP factors hereafter.

guidance or large asset purchases, it must be reinforced that this transformation simply differentiates between the target factor and the other two, removing the unexpected changes in the short rate. Therefore, it offers no structural interpretation to any of them specifically and both together represent the mix of non-standard policies systematically observed in the announcements.

Mathematically, the two restrictions require us to set the value of the asset's loadings on the two factors to 0, so that these are not responsible for any of its variability:

$$\text{i. } \Lambda_1 U_2 = 0, \quad \text{ii. } \Lambda_1 U_3 = 0,$$

where Λ_1 is the first row of the factor loadings, corresponding to the loads of the one month eonia swap. U_2 and U_3 correspond to the second and third column, respectively, of the rotation matrix. Again, so that the asset does not load on the factors, these transformations, representing the newly generated loadings, must be equal to zero.

This is sufficient to isolate non-standard actions as we intended. It does not, however, uniquely define the rotation matrix. For that, I resort to an ad hoc procedure. Note that even though the eonia had reached negative ground before, the European Central Bank reached its effective zero lower bound on the 16th of March when it set the deposit facility to -40 basis points and the fixed rate tender for main refinancing operations to 0. As a consequence, it is safe to assume that the target factor, which represents expectations on such policies, should be the least responsible for moving the markets after such date, as the central bank had extinguished their usefulness. Consequently, I set the third restriction so as to minimize the target factor's variability¹³:

$$\text{iii. Minimize}_{U_1} U_1' F^{elb'} F^{elb} U_1,$$

where U_1 is the first column of the rotation matrix and F^{elb} are the estimated factors after the 16th of March.

Given these three restrictions, the orthogonal matrix U is uniquely defined and can then be found by solving the following quadratic programming problem with quadratic constraints:

$$\begin{aligned} & \text{Minimize}_{U_1} U_1' F^{elb'} F^{elb} U_1 \\ & \text{subject to } \Lambda_1 U_2 = 0, \quad \Lambda_1 U_3 = 0, \quad U'U = I_3, \end{aligned} \tag{12}$$

¹³Represented by the sum of squares.

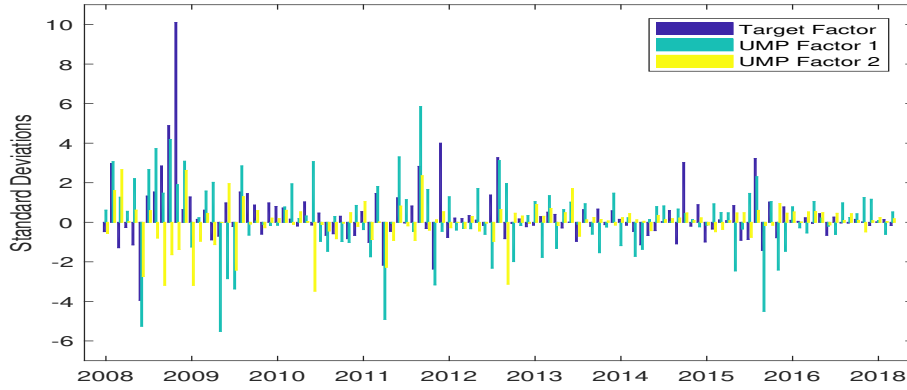


Figure 1: Rotated factors, expressed in standard deviations.

which is easily and only solvable through numerical methods, available in any computational package. Notice that the third constraint represents the orthogonality condition of the rotation matrix. The resulting factors, scaled by their standard deviations, are plotted in figure 1. I change their signs such that a positive value indicates a negative change in the one year eonia swap.

It first stands out the existence of three volatility clusters. The first starts in 2008 and lasts up to 2009, spanning most of the financial crisis period. The second, from 2011 to late 2012, portrays the sovereign crisis while the third, from mid 2015 to early 2016, shows the furthering of the quantitative easing program(s). Although by construction, it is relevant to observe that the target factor not only decreases its importance after 2016 but that it is also not always the predominant factor during the sample.

Furthermore, it is worth describing the 8th of October 2008's press release, the peak of the target factor, when the bank announced an easing policy, in cooperation with a group of other central banks, to provide liquidity to the financial system until required, as a response to the global financial crisis. On that same note, on the 4th of January 2011 the president announced an extension of the bond purchase programme and a special long-term refinancing operation with the intent of granting liquidity to the financial system, surprising the markets positively, as can be noted by the first UMP factor's value. Contrarily, at first sight, the highly negative reaction on the 12th of December 2015, most notably for the first UMP factor, might seem startling. Nonetheless, this reaction reflects the lower than expected package of measures to fight low inflation in the euro area, as one may conclude from the first question in the announcement Q&A: "...it seems like what you've done is a little bit on the low end of the range of what

the financial markets had expected...Why didn't you raise the monthly purchase amount? Why didn't you cut the deposit rate more?''.

The series generated needs to now be extended to the same monthly frequency as the empirical macroeconomic model. In order to do so, we follow the same methodology as Gertler and Karadi (2015). This extension method has two important properties. It, first, gives more emphasis to shocks occurring in the beginning of the month and, second, allows them to propagate for a given period of time. Intuitively, a shock striking in the beginning of the month should have a higher recorded impact than if that same shock hit the economy at the end of that period. At the same time, the shock's effects propagate into the future. Again, an unexpected change at the end of the period should have an impact on the next months' performance, as much of the reactions take time to materialize.

That being said, the extension proceeds as follows. For every day of the year, one first computes the cumulative sum of shocks until that date. In my method, the start of the sum depends on the month of the date. For example, if the day in question is in May, then one computes the cumulative sum of the shocks between that date and the past 29 days. After, one takes the average of these daily values for each month, resulting in the monthly series of shocks.

4.3 The effects of Monetary Policy Announcements on Asset Prices

I now try to uncover the resulting factors by studying how unexpected changes in the mix of monetary policy affect asset prices on days of policy announcements. To do so, I follow an event study methodology around the aforementioned time window and run the following regression using Ordinary Least Squares:

$$Y_{i,t} = \alpha + \beta_1 Z_{1,t} + \beta_2 Z_{2,t} + \beta_3 Z_{3,t} + v_{i,t}, \quad (13)$$

where the dependent variable is the change in the asset's index value and the independent variables are the estimated factors, on the 111 announcement dates. For the coefficients' p-values, heteroskedasticity and autocorrelation consistent standard errors are used. The results of regression (13) are reported in tables 1, 2 and 3.

Table 1: Event Regression Results for swaps.

	Constant (std. err.)	Target Factor (std. err.)	UMP Factor 1 (std. err.)	UMP Factor 2 (std. err.)	R^2
eonia swaps - 1M	.0063*** (.0024)	-.0208*** (.0043)	-.0001 (.0032)	.0003 (.0032)	.53
eonia swaps - 6M	.0023* (.0013)	-.0213*** (.0020)	-.0118*** (.0007)	-.0148*** (.0016)	.92
eonia swaps - 1Y	.0011 (.0021)	-.0208*** (.0022)	-.0212*** (.0012)	-.0223*** (.0031)	.90
eonia swaps - 5Y	.0074** (.0030)	.0021 (.0021)	-.0343*** (.0025)	-.0024 (.0056)	.81
eonia swaps - 10Y	.0049 (.0034)	.0139*** (.0027)	-.0314*** (.0030)	.0036 (.0072)	.66
Inflation swaps - 1Y	.0045 (.0039)	.0300*** (.0028)	.0068** (.0029)	.0529*** (.0061)	.77
Inflation swaps - 3Y	.0036 (.0040)	.0006 (.0050)	.0092*** (.0034)	.0098 (.0071)	.18
Inflation swaps - 5Y	.0056** (.0027)	-.0008 (.0040)	.0046** (.0020)	.0019 (.0039)	.09
Inflation swaps - 10Y	.0045** (.0022)	.0000 (.0026)	.0065*** (.0020)	.0004 (.0036)	.19

*, **, *** indicates statistical significance at the 10%, 5% and 1% significance level, respectively.

As predicted from the rank test, the results show that the factors behave independently from each other. For that matter, note that there are assets, such as the investment grade bonds index, that respond only to the two UMP factors, but not to the target factor. Furthermore, note that even those that are only affected by unconventional monetary policy may solely be affected by one of those two factors.

More specifically, with the exception of the 10 year eonia swap, note that both the eonia and inflation swaps, as maturity increases, seem to become more affected by unconventional monetary policy as the target factor turns statistically insignificant. Moreover, notice that at longer maturities only the first UMP factor remains meaningful in moving expectations. The second UMP factor appears to depict a more specific effect, affecting only (shorter) intermediate maturities, both on the eonia and inflation swaps. As expected, when expectations on intermediate rates decrease, inflation expectations increase due to the former's expansionary character.

In contrast, while the second UMP factor turns insignificant at longer maturities, german bond yields seem to remain affected by the target factor. Swanson (2017) too has similar results. The author also records a negative relationship between the treasury yield's maturity and significance of the forward guidance factor. In contrast, he finds a positive relationship with respect to the large asset purchases factor.

Table 2: Event Regression Results for Bond Yields.

	Constant (std. err.)	Target Factor (std. err.)	UMP Factor 1 (std. err.)	UMP Factor 2 (std. err.)	R ²
Italian Bonds - 6M	-.0071 (.0052)	-.0297*** (.0068)	.0032 (.0045)	-.0098* (.0058)	.40
Italian Bonds - 5Y	-.0053 (.0080)	-.0141* (.0083)	.0011 (.0128)	-.0257*** (.0098)	.08
Italian Bonds - 10Y	.0007 (.0083)	-.0048 (.0065)	.0000 (.0115)	-.0271** (.0128)	.07
Italian Bonds - 20Y	.0007 (.0069)	-.0046 (.0056)	.0025 (.0086)	-.0198* (.0105)	.05
German Bonds - 1Y	-.0068* (.0038)	-.0155** (.0048)	-.0206*** (.0020)	-.0200*** (.0039)	.76
German Bonds - 5Y	-.0027* (.0015)	.0047*** (.0013)	-.0384*** (.0012)	.0045*** (.0016)	.94
German Bonds - 10Y	-.0002 (.0022)	.0165*** (.0015)	-.0358*** (.0020)	.0092** (.0041)	.86
German Bonds - 20Y	.0032 (.0029)	.0150*** (.0024)	-.0301*** (.0026)	.0112 (.0046)	.70

*, **, *** indicates statistical significance at the 10%, 5% and 1% significance level, respectively.

The effect of both target and second UMP factors is, nonetheless, counter-intuitive as one would expect a co-movement between the whole yield curve. What we observe in turn, is that an expansionary policy, measured by the one month eonia swap decrease, increases the yield of German bonds with maturity above one year.

Focusing on longer maturity Italian bonds, despite the lower explanatory power, it is noteworthy to mention that only the second UMP factor remains statistically significant, while the first never is. Additionally, the target factor loses significance after five years of maturity.

Contrarily to bunds, not only do the second UMP coefficients' signs for Italian bonds seem to agree with the expansionary character of the others, but these remain significant for higher maturities in comparison.

Similarly surprising, equities¹⁴ seem to be solely affected by the target factor, with the same sign as that of the eonia swap. In turn, the bond index only answers to unconventional monetary policy, albeit with different signs between factors. Some of these results seem to be at odds with our understanding of monetary policy.

Firstly, all factors would be expected to have a meaningful impact on both types of assets. Swanson (2017), though, also finds that US corporates bond yields and spreads only respond to unconventional monetary policy. Contrarily, the author finds that the forward guidance

¹⁴The coefficients' size derives from the index magnitude. The standardization of the data to compute the factors implies that we do not need to do any transformation to the index's values.

Table 3: Event Regression Results for Private Indices and Exchange Rates.

	Constant (std. err.)	Target Factor (std. err.)	UMP Factor 1 (std. err.)	UMP Factor 2 (std. err.)	R^2
Equity Index	-3.339 (2.048)	-18.635*** (3.403)	3.135 (1.925)	1.636 (2.874)	.53
Investment Grade Bonds OAS Index	-.0024 (.0019)	-.0017 (.0013)	-.0122*** (.0016)	.0170*** (.0035)	.64
EUR/USD	-.0005 (.0008)	.0000 (.0008)	-.0045*** (.0005)	.0003 (.0008)	.51
EUR/CHF	-.0001 (.0004)	-.0003 (.0003)	-.0023*** (.0004)	.0009 (.0008)	.43
EUR/GBP	.0001 (.0004)	.0005 (.0004)	-.0020*** (.0003)	-.0004 (0.0004)	.38

*, **, *** indicates statistical significance at the 10%, 5% and 1% significance level, respectively.

factor also explains the US's equity index movements.

Secondly, the bonds spread index, capturing mainly corporate bonds, shows an increase in the spread from an expansionary policy for the second UMP factor. This would not be expected, specially considering the corporate purchase programs, which should work in the opposite direction. Nevertheless, it is true that the bonds also respond positively to this component.

Thirdly, notice that the target factor coefficient's sign for equities is again at odds with what one would expect. Notwithstanding, this stylized fact is also denoted in the work of Jarocinski and Karadi (2018). They observe that equities consistently do not respond to monetary policy as one would infer from the eonia swap movements, attributing this to economic information conveyed during announcements. This fact leads us to two preliminary conclusions. Firstly, it reinforces my previous statement that the two UMP factors only include systematic information that is not responsible for moving the short rate. Secondly, it shows that the target factor may include more information regarding monetary policy than just conventional measures. As such, it will most likely provide similar results to the literature who only uses an eonia swap to measure policy surprises.

Finally, the exchange rates do react to unconventional monetary policy, although this effect is only statistically significant for the first UMP factor. This finding in particular, adds evidence supporting the effect of non-standard measures on foreign exchange markets, although only due to one facet of these. Swanson (2017), in contrast, finds that every factor affects the US dollar's exchange rate. In addition, the effect is qualitatively homogeneous across currencies and is according to theory, where an expansionary policy should and does decrease the nominal value

of the euro against other currencies.

All in all, these results constitute evidence that the two UMP factors merely represent non-standard measures. In particular, the first UMP factor seems to be in accordance with the presented literature on the financial effects of unconventional policy. The second UMP factor, instead, appears to be more specific and not easily identifiable from previous studies. Furthermore, the target factor suffers from a pitfall already denoted in previous work. A possible solution would be to use further ad hoc assumptions, although doing this would harm our approach's simplicity. Finally, it might be the case that some information on atypical measures is included in the target factor.

5 Data, Estimation and Results

In this section I first present the data used together with the results from the benchmark SVAR model. More details on transformations and data sources are provided in appendix. After, I delve deeper into the mechanisms of transmission of large scale asset purchases. Along the section I compare my results with those of previous literature.

5.1 Benchmark SVAR: Large Scale Asset Purchases

The period after the financial crisis is still relatively short to conduct a quarterly macroeconomic analysis. I, therefore, use monthly data in order to examine the effects of large scale asset purchases, as portrayed by our constructed instrument(s), on the euro area aggregate economy. The working dataset, i.e., disregarding the lags in the model and the differences taken, span from January 2009 to March 2018 and comprises 111 observations.

Given the continuous use of asset purchases and our intermediate results, it must be that at least one of our UMP factors portrays central bank's balance sheet size measures. In order to test such claim, I construct a benchmark SVAR model using public information on the total value of the ECB's assets¹⁵.

¹⁵I do not include the eonia rate as policy tool since it requires more lags than our data would permit. I provide the results of the model in appendix, using only 3 lags. The results do not change and the interest rate falls throughout.

Aggregate macroeconomic and sectoral accounts at a monthly frequency are not available at the euro aggregate level. As a result, we resort to the index of total industrial production as a proxy for output. For prices, we use the total harmonized consumer price index (hcpi) excluding energy and food.

I choose here to add the non-adjusted reference price for crude oil in Europe, the Brent. The common small-scale SVAR model used to analyse monetary policy tends to suffer from the well-known price puzzle. Leeper et al. (1996) point out that this is due to the exclusion of forward-looking variables. These are very important for the central bank's reaction function as expectation management is a crucial task of said institution. Commodity prices are known to have such property and may act as a solution to this problem.

I use the Akaike, Bayesian information and Hanna-Quinn criteria to determine the number of lags. The first two indicate a model of order one whereas the latter points for a three lagged system. I take the latter and use 3 lags. The resulting estimates are obviously stationary and the residuals show no statistically significant signs of autocorrelation, even up to one and a half years, supporting our choice.

In order to determine the validity of my instruments, I regress them individually on each residual of the model. The first stage F-statistics provides statistical evidence, at the 1% significance level, for the relevance of the target and first UMP factors. It, therefore, invalidates the use of the second UMP factor as an external instrument for large scale asset purchases. The regression on first UMP factor has an r-squared of 12.4% while that of the target factor is of 9.0%. Contrarily to the first UMP factor, the latter does not respect the necessary assumption of exogeneity due to its statistically significant coefficient for the hcpi, presenting a very high F-statistic. These results provide further evidence that the factor may explain more than just unexpected conventional monetary policy measures. As a result, we may also not make use of it for identification purposes. Consequently, I use the first UMP factor as a proxy variable, proven to respect all the required assumptions for our purpose.

The structural IRFs¹⁶ to an expansionary 25 basis points shock of the ECB's balance sheet are displayed in figure 2. I include one standard deviation confidence bands that result from a

¹⁶Cumulative IRFs are presented if the series were first differenced.

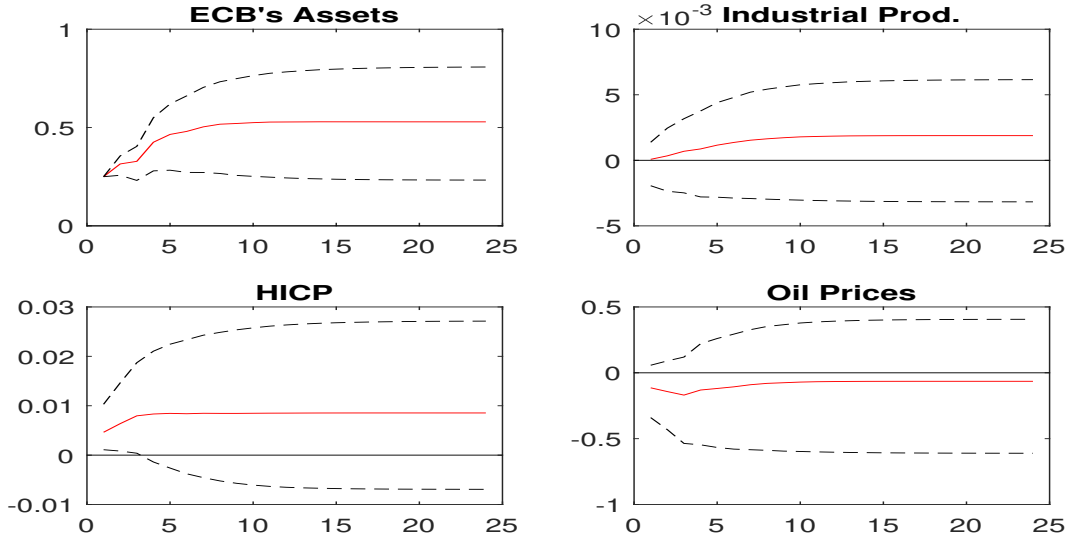


Figure 2: Structural IRFs to an expansionary 25 bp balance sheet shock, benchmark SVAR.

wild bootstrap using a standard normal distribution and 5000 iterations, following Djogbenou et al. (2015). Given a strong instrument like mine, this approach is valid even in the presence of heterogeneity. Both stages of the methodology are included, thus, avoiding, as Gertler and Karadi (2015) point out, any 'regressed generator' problems.

As a validation of this method, I first highlight the absence of both the price and output puzzle. In fact, contrarily to previous literature findings, the latter increase shows more inertia than that of the former which reacts within the period. Price's error bands, nevertheless, remain positive for almost 4 months while the latter's, simultaneously, never are. Both appear to be level effects, as they remain at their peak for at least two years. Contrarily to some 'fears', the full effects of this policy on prices appear to materialize immediately. Besides, the results exhibit a neutrality property of the balance sheet size policy since production is not significantly, both economically and statistically, affected by it.

5.2 Transmission Channels

We now set out to understand what transmission channels for large scale asset purchases may be at play. In order to do so, our baseline approach, common to the rest of the small-scale VAR literature, is to alternate individually between the variables of interest, adding them as a fifth variable to the benchmark model. We may then inspect their respective structural impulse response functions to the same expansionary balance sheet shock as in the previous subsection.

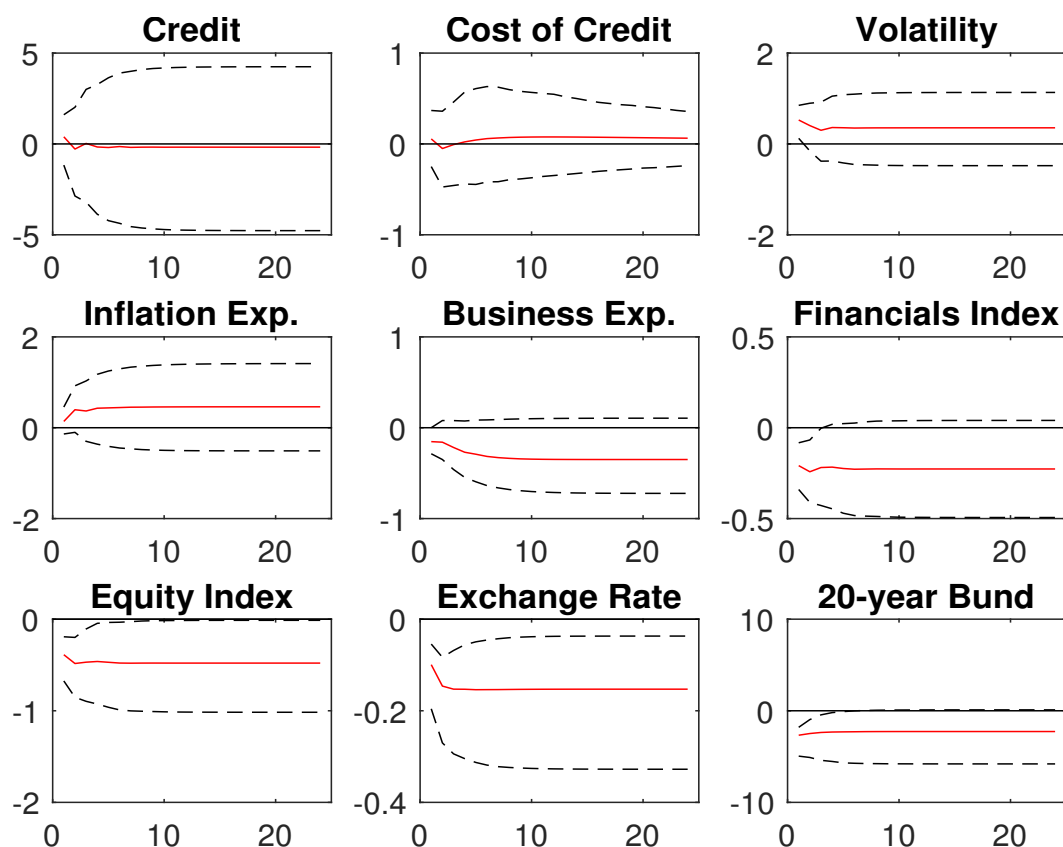


Figure 3: Structural IRFs to a 0.25 balance sheet shock, fifth variable SVAR.

All results are displayed in figure 3.

I first highlight the activation of the portfolio rebalancing channel as evidenced from the decrease in the long term bund yield, which I use as a proxy for safe assets. In order for this channel to work, it must be that safer assets suffer a depression in yield, as we observe here, so as to offer lower returns to investors and subsequently incentivize for a portfolio reshuffling. Nonetheless, this channel can only be deemed successful if it actually materializes into a quest for alternative assets.

To check this outcome I focus on equities, while also inspecting financial sector's market returns and market uncertainty. With that goal in mind, I resort to the Volatility STOXX, the STOXX50 and the financials STOXX indices which portray volatility and equity returns in the euro area, respectively. Both series provide a clear picture against financial markets benefiting from the policy. Starting with uncertainty, we find the same result as in previous literature, which surprisingly shows an enlarging in volatility. This result, therefore, contradicts the argument that quantitative easing, among other potential channels, works by diminishing un-

certainty. On top of this, we observe that both the broad equity and the financial sector equity indices decrease on impact, as well as through time. The financial sector like it has been argued, has not benefited from an environment of low interest rates and decreasing margins, thus, explaining this result. The equity market's result is more puzzling as asset prices should increase given the crowding out effect on safer assets or the decrease of interest rates. This offers further evidence against some sign restrictions presented in section 2.

Last for security markets, we turn to the exchange rate channel and verify that this is clearly activated, depressing immediately on impact and remaining as such for the rest of the period.

Turning to real effects, I analyse the pass-through of extra liquidity in the financial system to credit for the public. In order to assess its impact, I inspect both the cost and volume of credit in the economy. This allows us to understand if this credit easing policy actually materializes into better credit conditions for the economic system. To assess the cost of credit, I use the annualized agreed rate for consumption of the household sector in the euro area¹⁷. Additionally, for the volume of credit I use the monthly flow of loans to both households and non-financial corporations, summed together.

Offering fresh results on this topic, both series provide a clear picture against more favourable credit conditions. Neither the flow nor the cost of credit appear to significantly change, remaining near their steady state values throughout. These results seem to portray the state of the euro area after the beginning of the quantitative easing programmes, when we could not really conclude for facilitated credit from MFIs to the real economy.

An alternative but similarly important mechanism of transmission is that of expectations. As such, I use two indicators, one depicting business prospects and the other inflation outlooks. The first is the eurozone's business index and the second an inflation expectations index. The first indicates that business expectations actually decrease on impact, in the virtue of an expansionary policy. Contrarily, the inflation expectations index appears to rise, even though the error bands still capture its steady state value. Both series appear not to suffer a significant impact when considering a longer horizon and offer proof that if this channel is activated, it is very mildly so.

Methodologically though, we may not ignore the fact that the external instrument is ex-

¹⁷The results are in everything similar to using an equivalent rate but for house purchase reasons.

tremely correlated with the long term bund yields, the exchange rate and the equity indices - as one would predict from section 4 - which will extensively bias the results. Therefore, as a robustness check, I estimate our benchmark model using these variables as policy indicators, one at a time, in place of the balance sheet variable. The subsequent responses are defined solely by the external identification method, thus, depicting this same expansionary non-standard measure. Subsequently, we may shock each of them negatively, as observed here, and confirm that the results are similar overall, with a significant rise in prices and a mild effect on output. Adding to the obvious relevance depicted by the very high F-statistic, this robustness check grants us reassurance of our previous conclusions' validity.

6 Conclusion

Resorting to an agnostic methodology, I provide evidence contradicting previous results on asset purchases' effects in the euro area. More specifically, we neither document a rise in equity prices nor improved business expectations. Similarly, credit conditions do not really benefit from an expansion of the balance sheet size. Nonetheless, to the advantage of policy making, this measure may be neutral since we do not witness a significant reaction from real production.

These results are, nevertheless, case-specific and cannot be generalized for every central bank. Even though we are focusing only on size, composition and, thus, the particular type of asset purchases, which are not controlled for explicitly here but arguably done so by the external instrument, matter. As a result, conclusions could be changed were asset purchases conducted differently.

The failure to obtain additional data, among other, related to corporate bonds and credit spreads, has prevented me from both extinguishing every potential transmission mechanism predicted in the theoretical literature and delving deeper into those briefly studied here. This means there is still ground for deeper research on these matters.

To conclude, in terms of the specific methodology, even though we were able to extract valuable information from policy announcements, it must be restated that we fail to offer a complete interpretation of every dimension retrieved. Therefore, a need to further study several of the ECB's communication facets stems from our statistical exercise.

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Appendices

A Dataset

This appendix contains a list of the series in our dataset with information regarding transformations made, seasonal adjustments and sources. All data are of monthly frequency and span from September 2008 to March 2018. All variables cover the euro area, either all the 19 countries or the ECB's (changing) coverage definition. Abbreviations and codes are as follows:

Transformations:

- 1 - None
- 2 - First Differenced
- 4 - Logarithmized
- 5 - Logarithmized and First Differenced

Seasonal Adjustment:

- WDSA - Calendar and Seasonally Adjusted
- SA - Seasonally but not Calendar Adjusted
- NSA - Neither Seasonally nor Calendar Adjusted

Source:

- EC - European Commission

Description	Transformation	Seasonal Adjustment	Source
Index of Total Industrial Production	5	WDSA	ECB sdw
The Harmonised Index of Consumer Prices Total Excluding Energy and Food	5	WDSA	ECB sdw
Crude Oil Prices: Brent Europe - Monthly Average, Dollars per Barrel	5	NSA	FRED
Eurosystem Balance Sheet Total Assets - End of Period	5	NSA	ECB sdw
Euro vs Dollar Spot Exchange Rate Monthly Average	5	NSA	ECB sdw
20-year German Bunds' Yields Monthly Average	1	NSA	ECB sdw
Euro-zone Business Climate Indicator Monthly Data	5	SA	EC
Consumer Opinion Surveys: Future Tendency for Inflation - Euro Area	5	SA	FRED
Dow Jones Euro Stoxx 50 Price Index Monthly Average	5	NSA	Datastream
Dow Jones Euro Stoxx Financials Index Monthly Average	5	NSA	Datastream
Euro Stoxx 50 Volatility Index Monthly Sum	5	NSA	STOXX
Loans to NFC and Households Annual percentage rate of charge, Loans for consumption excluding revolving loans and overdrafts, convenience and extended credit card debt - Monthly Average	5 2	WDSA WDSA	ECB sdw ECB sdw

B Additional Impulse Response Functions

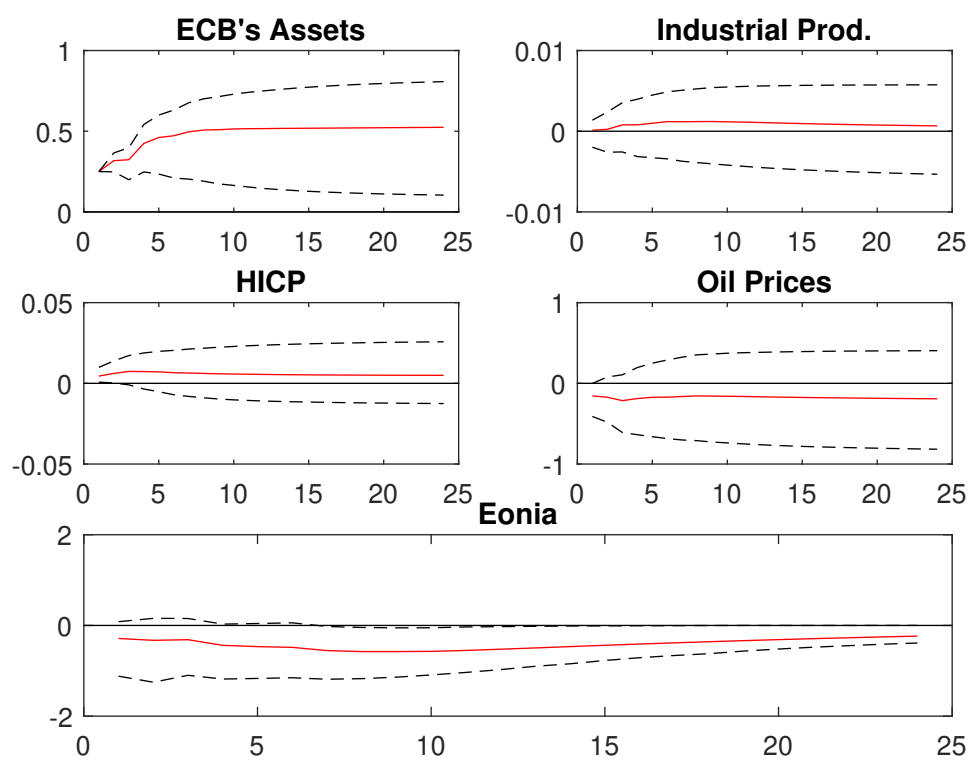


Figure 4: Structural IRFs to an expansionary 25 bp balance sheet shock, benchmark SVAR + Eonia.

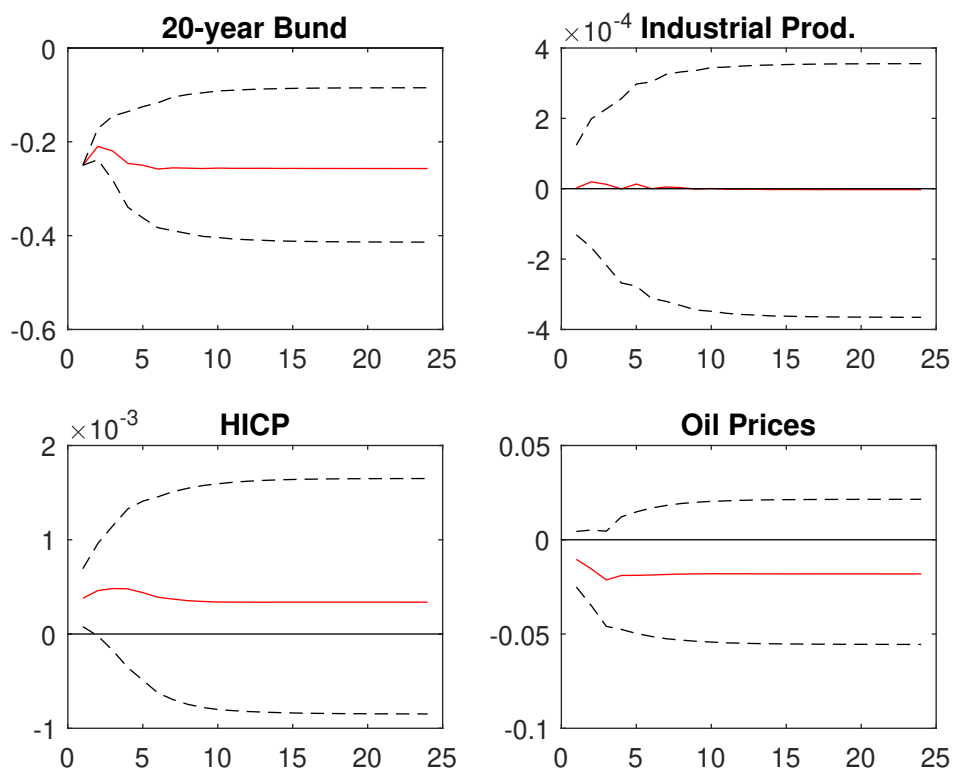


Figure 5: Structural IRFs to a -25 bp 20-year german bund shock, robustness check.

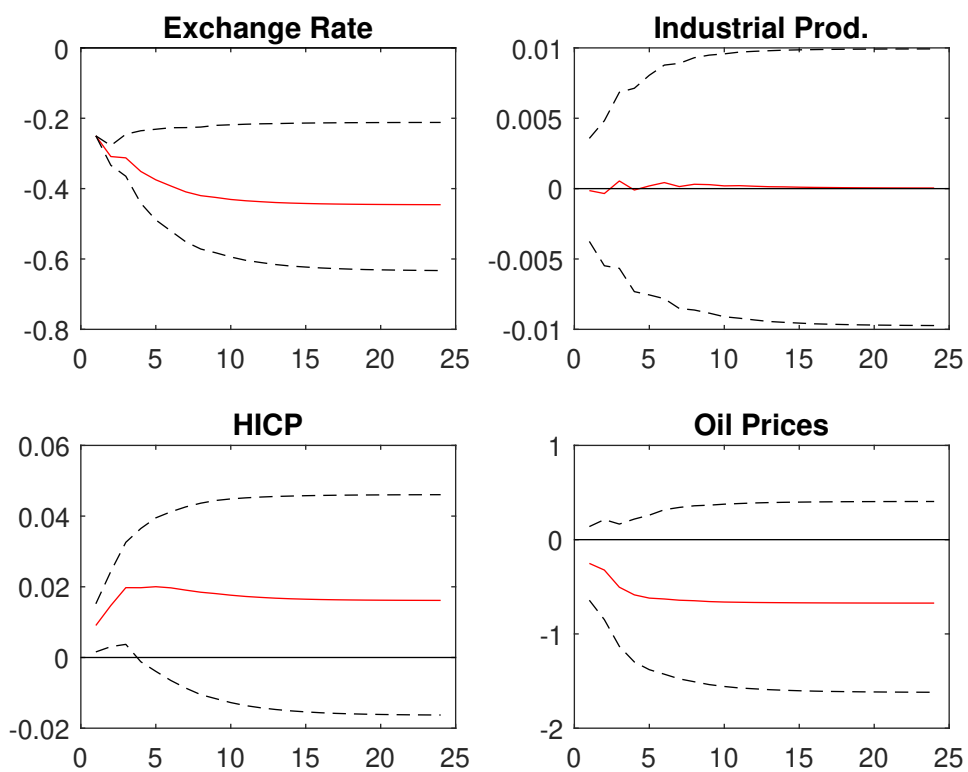


Figure 6: Structural IRFs to a -25 bp exchange rate shock, robustness check.

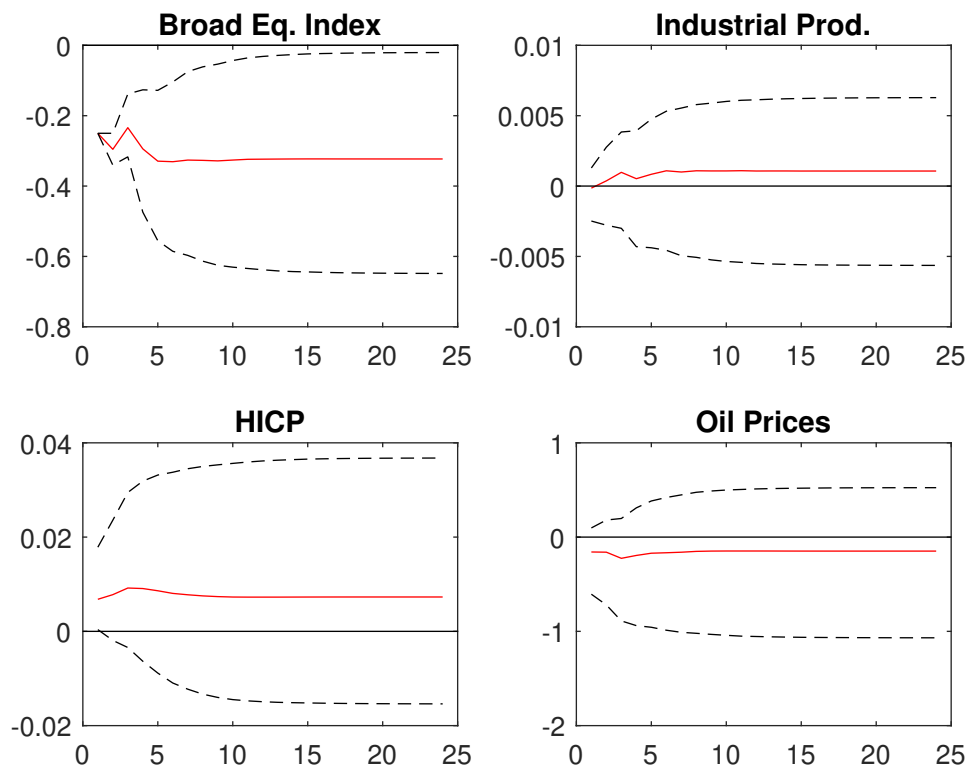


Figure 7: Structural IRFs to a -25 bp overall equity index shock, robustness check.

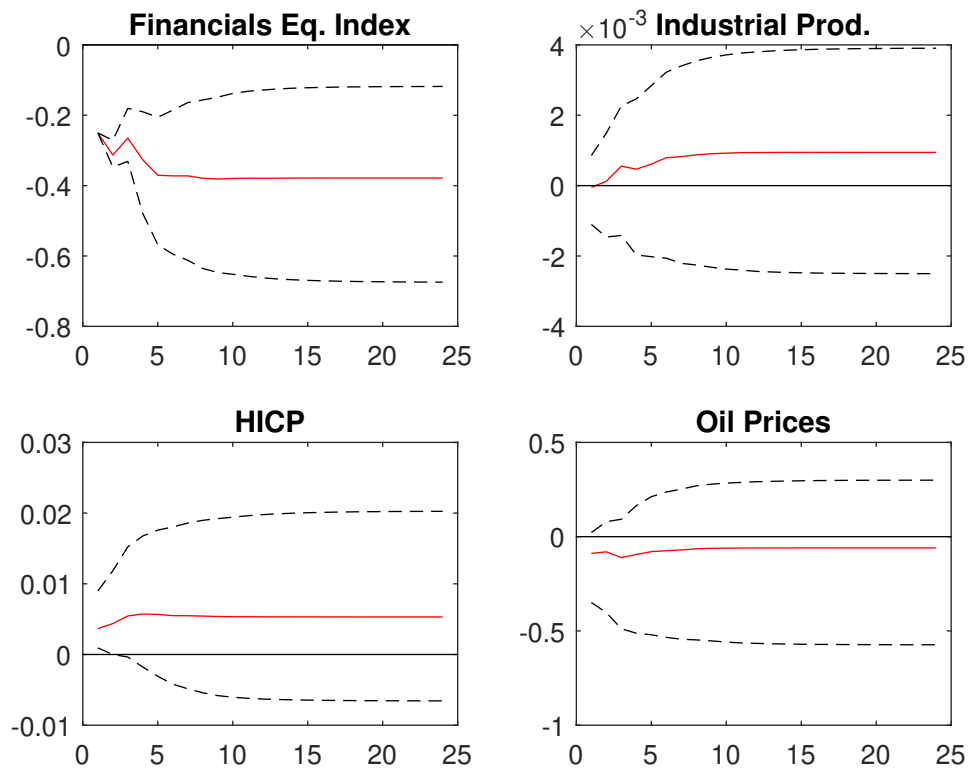


Figure 8: Structural IRFs to a -25 bp financial sector's equity index shock, robustness check.